Chapter 7. Bioaccumulation of Contaminants in Fish Tissues

INTRODUCTION

Bottom dwelling (i.e., demersal) fishes are collected as part of the South Bay Ocean Outfall (SBOO) monitoring program to assess the accumulation of contaminants in their tissues. Bioaccumulation of contaminants in fish occurs through the biological uptake and retention of chemical contaminants derived via various exposure pathways (U.S. EPA 2000). The main exposure routes for demersal fishes include uptake of dissolved chemicals in seawater and the ingestion and assimilation of pollutants contained in different food sources (Rand 1995). Because of their proximity to seafloor sediments, these fish may also accumulate contaminants through ingestion of suspended particulates or sediments that contain pollutants. For this reason, the levels of many contaminants in the tissues of demersal fish are often related to those found in the environment (Schiff and Allen 1997), thus making these types of assessments useful in biomonitoring programs.

The bioaccumulation portion of the South Bay monitoring program consists of two components: (1) liver tissues are analyzed for trawl-caught fishes; (2) muscle tissues are analyzed for fishes collected by hook and line (rig fishing). Species of fish collected by trawling activities (see Chapter 6) are representative of the general demersal fish community, and certain species are targeted based on their prevalence in the community and therefore ecological significance. The chemical analysis of liver tissues in these fish is especially important for assessing population effects because this is the organ where contaminants typically concentrate (i.e., bioaccumulate). In contrast, fishes targeted for capture by rig fishing represent species that are characteristic of a typical sport fisher's catch, and are therefore considered of recreational and commercial importance and more directly relevant to human health concerns. Consequently, muscle tissue is analyzed from these fishes because it is the tissue most often consumed by humans, and therefore the results may have public health implications.

This chapter presents the results of all tissue analyses that were performed on fishes collected in the SBOO region during 2009. All liver and muscle samples were analyzed for contaminants as specified in the NPDES discharge permits that govern the SBOO monitoring program (see Chapter 1). Most of these contaminants are also sampled for the National Oceanic and Atmospheric Administration (NOAA) National Status and Trends Program. NOAA initiated this program to detect and monitor changes in the environmental quality of the nation's estuarine and coastal waters by tracking contaminants thought to be of environmental concern (Lauenstein and Cantillo 1993).

Materials and Methods

Field Collection

Fishes were collected during April and October of 2009 at seven trawl and two rig fishing stations (Figure 7.1). California scorpionfish (*Scorpaena guttata*), English sole (*Parophrys vetulus*), hornyhead turbot (*Pleuronichthys verticalis*), and longfin sanddab (*Citharichthys xanthostigma*) were collected for analysis of liver tissues from the trawling stations, while California scorpionfish, brown rockfish (*Sebastes auriculatus*), calico rockfish (*Sebastes dallii*), copper rockfish (*Sebastes caurinus*), vermilion rockfish (*Sebastes miniatus*), and yellowtail rockfish (*Sebastes flavidus*) were collected for analysis of muscle tissues at the two rig fishing stations (see Table 7.1). All trawl-caught fishes were collected following City of San Diego guidelines (see Chapter 6 for a description of collection methods). Efforts to collect the targeted fish species at the trawl stations were limited to five 10-minute (bottom time) trawls per site. Fishes collected at the two rig fishing stations were caught within 1 km of the station location using standard rod and reel procedures; fishing effort was limited to 5 hours at each of these stations. Occasionally, insufficient numbers of the target species were obtained despite this effort, thus resulting in reduced number of composite samples at a particular station.

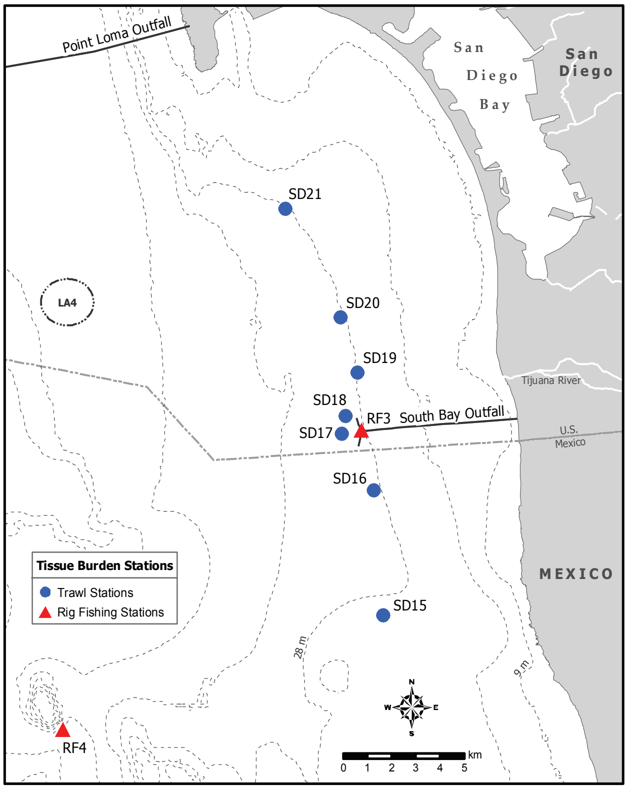

Figure 7.1
Otter trawl and rig fishing stations for the South Bay Ocean Outfall Monitoring Program.

In order to facilitate the collection of sufficient tissue for subsequent chemical analysis, only fish ≥13 cm in standard length were retained. These fish were sorted into no more than three composite samples per station, each containing a minimum of three individuals. Composite samples were typically made up of a single species; the only exceptions were samples that consisted of mixed species of rockfish as indicated in Table 7.1. All fish collected were wrapped in aluminum foil, labeled, sealed in re-sealable plastic bags, placed on dry ice, and then transported to the City's Marine Biology Laboratory where they were held in the freezer at -80°C until dissection and tissue processing.

Tissue Processing and Chemical Analyses

All dissections were performed according to standard techniques for tissue analysis. A brief summary follows, but see City of San Diego (2004) for additional details. Prior to dissection, each fish was partially defrosted and then cleaned with a paper towel to remove loose scales and excess mucus. The standard length (cm) and weight (g) of each fish were recorded (Appendix F.1). Dissections were carried out on Teflon® pads that were cleaned between samples. The tissues (liver or muscle) from each dissected fish were then placed in separate glass jars for each composite sample, sealed, labeled, and stored in a freezer at -20°C prior to chemical analyses. All samples were subsequently delivered to the City's Wastewater Chemistry Services Laboratory for analysis within 10 days of dissection.

The chemical constituents analyzed for each tissue sample were measured on a wet weight basis, and included trace metals, chlorinated pesticides, polychlorinated biphenyl compounds (PCBs), and polycyclic aromatic hydrocarbons (PAHs) (see Appendix F.2). Metals were measured in units of mg/kg and are expressed herein as parts per million (ppm), while pesticides, PCBs, and PAHs were measured as µg/kg and expressed as parts per billion (ppb). This report includes estimated values for some parameters determined to be present in a sample with high confidence (i.e., peaks confirmed by mass-spectrometry), but that otherwise occurred at levels below the method detection limit (MDL). A detailed description of the protocols for chemical analyses is available in City of San Diego (2010).

Data Analyses

Data summaries included detection rates (i.e., number of reported values/number of samples), minimum, maximum, and mean detected values of each parameter by species. Totals for DDT, PCBs, HCH, chlordane, and PAHs were calculated as the sum of the detected constituents (i.e., total PCB = sum of all congeners detected). The detected values for each individual constituent are listed in Appendix F.3. In addition, the distribution of frequently detected contaminants in fishes collected in the SBOO region was assessed by

Table 7.1
Species of fish collected for tissue analysis at each SBOO trawl and rig fishing station during April and October 2009.

Survey	Station	Composite 1	Composite 2	Composite 3
April 2009	RF3	Brown rockfish	Brown rockfish	Mixed rockfish [a]
	RF4	California scorpionfish	California scorpionfish	California scorpionfish
	SD15	English sole	Hornyhead turbot	No sample [c]
	SD16	Longfin sanddab	Hornyhead turbot [b]	No sample [c]
	SD17	Longfin sanddab	Longfin sanddab	Longfin sanddab
	SD18	Longfin sanddab	Longfin sanddab	Longfin sanddab
	SD19	Longfin sanddab [b]	Hornyhead turbot [b]	No sample [c]
	SD20	No sample [c]	No sample [c]	No sample [c]
	SD21	Longfin sanddab	Longfin sanddab	Hornyhead turbot
October 2009	RF3	Brown rockfish	Brown rockfish	Mixed rockfish [d]
	RF4	California scorpionfish	California scorpionfish	California scorpionfish
	SD15	Hornyhead turbot [b]	No sample [c]	No sample [c]
	SD16	Hornyhead turbot	Longfin sanddab	Longfin sanddab
	SD17	Hornyhead turbot	California scorpionfish	Hornyhead turbot
	SD18	Hornyhead turbot	Hornyhead turbot	California scorpionfish
	SD19	Longfin sanddab	Longfin sanddab	Longfin sanddab
	SD20	Longfin sanddab	Longfin sanddab [e]	Hornyhead turbot
	SD21	Hornyhead turbot	Hornyhead turbot	California scorpionfish

[a] Includes vermilion, calico, copper, and yellowtail rockfish; [b] Not enough tissue to analyze metals; [c] Insufficient fish collected (see text); [d] Includes brown and vermilion rockfish; [e] PAH failed QC, not enough tissue to re-analyze.

comparing concentrations in fishes collected at "nearfield" stations located within a kilometer of the SBOO (SD17, SD18, RF3) to those from "farfield" stations located farther away to the south (SD15, SD16), north (SD19–SD21), and west (RF4). When available, concentrations were also compared to values detected during the pre-discharge period (1995–1998). Because concentrations of contaminants varied so much among the species collected, only intra-species comparisons were used for these evaluations.

Finally, contaminant concentrations found in the muscle tissues of fishes collected as part of the SBOO monitoring program were compared to state, national, and international limits and standards to address human health concerns. These include: (1) the California Office of Environmental Health Hazard Assessment (OEHHA), which has developed fish contaminant goals for chlordane, DDT, methylmercury, PCBs, and selenium (Klasing and Brodberg 2008); (2) the United States Food and Drug Administration (U.S. FDA), which has set limits on the amount of mercury, total DDT, and chlordane in seafood that is to be sold for human consumption (see Mearns et al. 1991); (3) international standards for acceptable concentrations of various metals and DDT (see Mearns et al. 1991).

Results and Discussion

Contaminants in Trawl-Caught Fishes

Metals

Thirteen metals occurred in ≥70% of the liver samples analyzed from trawl-caught fishes in 2009, including aluminum, arsenic, barium, cadmium, chromium, copper, iron, manganese, mercury, selenium, silver, tin, and zinc (Table 7.2). Another four metals (antimony, beryllium, lead, thallium) were also detected, but less frequently at rates between 3–40%. Nickel was not detected in any of the liver samples collected during 2009. Tissue concentrations of most metals were <30 ppm over all species. Exceptions occurred for aluminum, iron, and zinc, which all had concentrations >60 ppm in at least one sample. Several metals occurred in quantities that varied greatly among the different species of fish. For example, the highest values of beryllium, chromium, copper, iron, mercury, silver, thallium, and zinc occurred in samples of California scorpionfish. In contrast, the highest values of aluminum, antimony, barium, lead, manganese, selenium, and tin occurred in samples of longfin sanddab. These differences are not unexpected, as it has been well documented that the bioaccumulation of contaminants can vary greatly between fish species due to differences in physiology and life history (see Groce 2002 and references therein).

Intra-species comparisons between nearfield and farfield stations suggest that there was no clear relationship between contaminant loads in fish liver tissues and proximity to the outfall (Figure 7.2). Contaminant concentrations were generally similar among stations and most samples had levels of metals close to or below the maximum levels detected in the same species prior to discharge. Exceptions occurred for aluminum, arsenic, cadmium, copper, manganese, mercury, and zinc, which had between 1 and 9 samples (out of 30 total) that exceeded pre-discharge maximums. These relatively high concentrations occurred throughout the region and showed no pattern relative to the outfall.

Pesticides

Several chlorinated pesticides were detected in fish liver tissues during the 2009 trawl surveys (Table 7.3). DDT was found in every tissue sample with total DDT concentrations ranging from 26 to 2802 ppb. The most frequently detected DDT constituent was p,p-DDE, which was found in 100% of these samples at concentrations up to 2700 ppb (Appendix F.3). Other DDT constituents detected frequently (i.e., >50% of the samples) included o,p-DDE and p,p-DDD. Other pesticides detected in fish tissues during the past year included hexachlorobenzene (HCB) in 65% of the samples at concentrations up to 4.7 ppb, chlordane in 9% of the samples at concentrations up to about 20 ppb, and endrin in 6% of the samples at concentrations up to 210 ppb. Total chlordane consisted of trans-nonachlor in two samples of California scorpionfish, whereas it consisted of alpha and gamma-chlordane in a single sample of hornyhead turbot (Appendix F.3).

Most pesticide concentrations were near or below the maximum levels detected in the same species prior to wastewater discharge (Figure 7.3). Only one sample of hornyhead turbot collected from station SD20 had values of total DDT that exceeded the pre-discharge maximum. In addition, no clear relationship could be determined between concentrations of these pesticides in fish tissues and proximity to the outfall (Figure 7.3), or with lipid content, or with the size of the fishes (length or weight) used in each composite.

PAHs and PCBs

PAHs were not detected in fish liver samples during 2009. In contrast, PCBs occurred in every tissue sample (Table 7.3). PCB 153/168 was the most frequently detected congener in liver tissues as it was found in every sample; other frequently detected congeners (i.e., >70%) included PCB 99, PCB 101, PCB 118, PCB 138, PCB 180, and PCB 187 (Appendix F.3). Total PCB concentrations were highly variable in South Bay fish tissues, ranging from 2.4 to 841.9 ppb (Table 7.3). These concentrations were substantially less than pre-discharge values, with no clear relationship with proximity to the outfall (Figure 7.3), lipid content, or with the size of the fishes used in each composite.

Contaminants in Fishes Collected by Rig Fishing

Aluminum, arsenic, barium, chromium, copper, iron, mercury, selenium, and zinc occurred in ≥75% of the muscle tissue samples collected from the two rig fishing stations in 2009 (Table 7.4).

Table 7.2

Summary of metals in liver tissues of fishes collected at SBOO trawl stations during 2009. Data include the number of detected values (*n*), as well as minimum (Min), maximum (Max) and mean detected concentrations for each species. Concentrations are expressed as parts per million (ppm); the number of samples per species is indicated in parentheses. See Appendix F.2 for MDLs and names for each metal represented by periodic table symbol.

	Al	Sb	As	Ba	Be	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Tl	Sn	Zn
California scorpionfish																		
n (out of 3)	3	0	3	2	1	3	1	3	3	1	3	3	0	3	3	1	2	3
Min	4.8	—	0.8	0.048	0.014	2.61	0.439	13.0	174	0.112	0.29	0.276	—	0.57	0.181	1.58	0.36	95.5
Max	11.4	—	1.5	0.093	0.014	3.85	0.439	16.0	233	0.112	0.71	0.441	—	1.12	0.379	1.58	0.44	153.0
Mean	7.2	—	1.1	0.070	0.014	3.27	0.439	14.0	203	0.112	0.50	0.356	—	0.91	0.268	1.58	0.40	118.5
English sole																		
n (out of 1)	1	0	1	1	0	1	1	1	1	1	1	1	0	1	0	0	1	1
Min	18.0	—	28.9	0.175	—	1.98	0.205	9.8	196	0.367	1.90	0.082	—	1.37	—	—	2.66	37.3
Max	18.0	—	28.9	0.175	—	1.98	0.205	9.8	196	0.367	1.90	0.082	—	1.37	—	—	2.66	37.3
Mean	18.0	—	28.9	0.175	—	1.98	0.205	9.8	196	0.367	1.90	0.082	—	1.37	—	—	2.66	37.3
Hornyhead turbot																		
n (out of 10)	7	0	10	6	0	10	6	10	10	0	10	10	0	10	8	0	10	10
Min	3.4	—	2.3	0.037	—	2.17	0.107	4.1	40	—	0.81	0.064	—	0.50	0.050	—	0.23	23.0
Max	28.5	—	8.1	0.175	—	8.24	0.303	8.8	106	—	1.94	0.202	—	1.58	0.276	—	1.69	97.4
Mean	9.4	—	4.0	0.086	—	5.23	0.176	6.6	59	—	1.24	0.128	—	0.90	0.144	—	0.59	49.6
Longfin sanddab																		
n (out of 16)	16	6	16	15	1	16	13	16	16	10	16	16	0	16	12	0	14	16
Min	4.3	0.207	2.6	0.032	0.009	1.22	0.072	4.2	35	0.121	0.68	0.042	—	1.02	0.065	—	0.23	13.9
Max	60.7	0.811	17.6	1.520	0.009	6.20	0.406	12.4	155	1.580	2.65	0.170	—	1.77	0.186	—	3.66	43.6
Mean	19.3	0.382	8.0	0.266	0.009	2.64	0.244	7.9	101	0.398	1.52	0.087	—	1.36	0.121	—	1.87	27.2
All Species:																		
Detection Rate (%)	90	20	100	80	7	100	70	100	100	40	100	100	0	100	77	3	90	100
Max Value	60.7	0.811	28.9	1.520	0.014	8.24	0.439	16.0	233	1.580	2.65	0.441	—	1.77	0.379	1.58	3.66	153.0

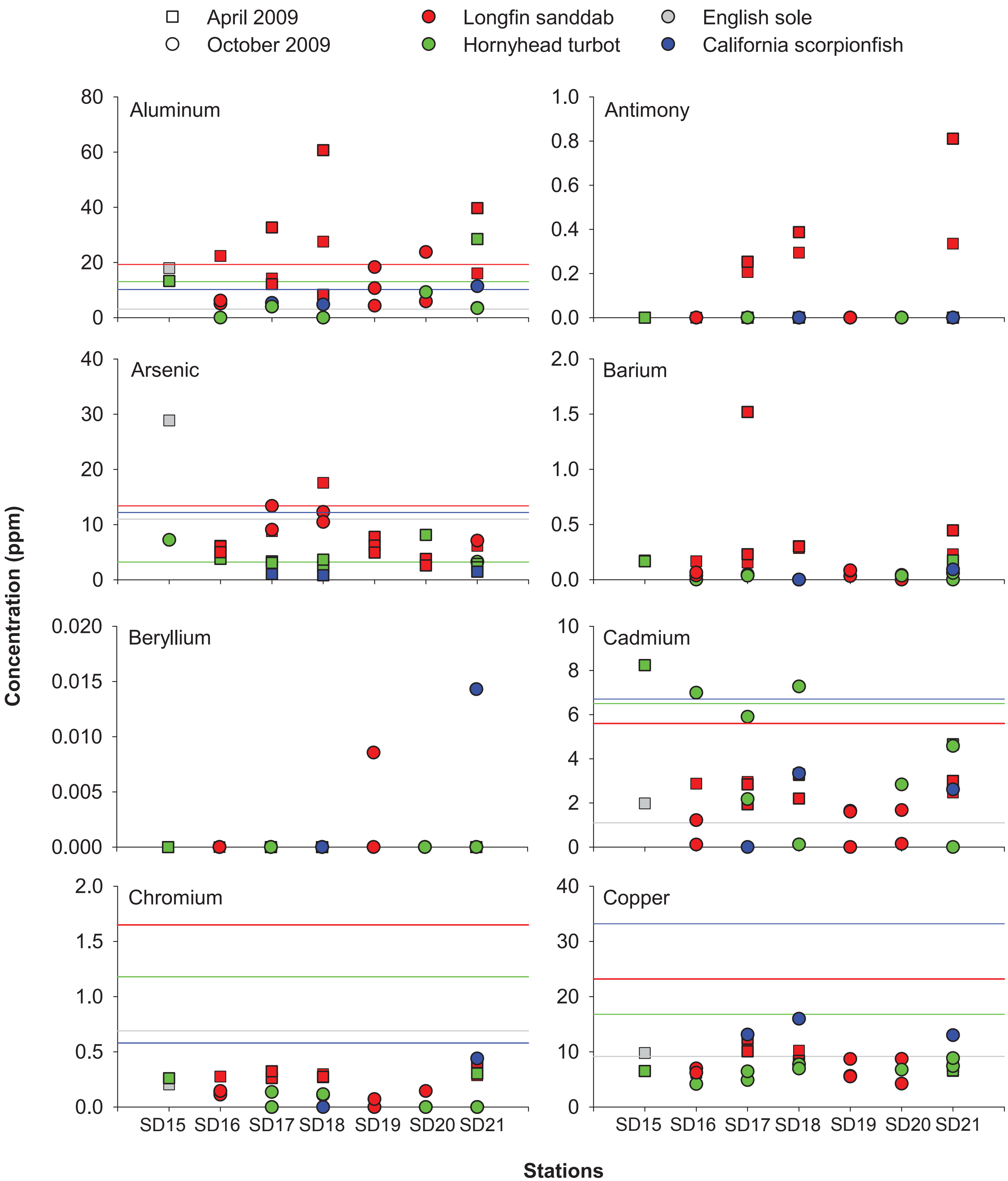

Figure 7.2

Concentrations of frequently detected metals in liver tissues of fishes collected from each SBOO trawl station during 2009. Reference lines are maximum values detected during the pre-discharge period (1995–1998) for each species; antimony, barium, beryllium, and tin were not detected during the pre-discharge period because of substantially higher detection limits. Therefore, no reference lines are present for these contaminants. To differentiate between missing values (i.e., samples that were not collected or not analyzed; see Table 7.1) and non-detects, zeros were added as placed holders for non-detected values.

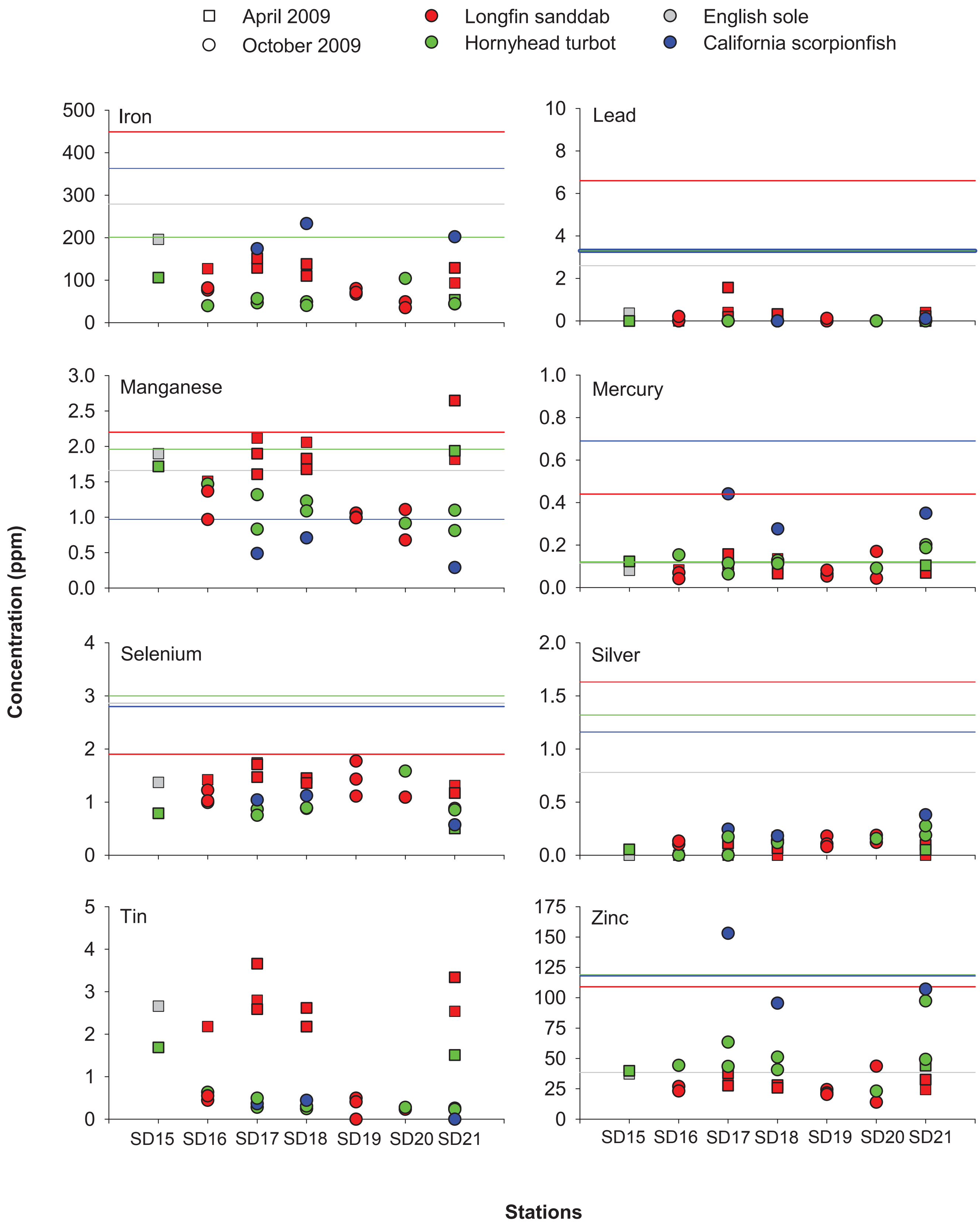

Figure 7.2 *continued*

Manganese and tin were only detected in 50% of the samples, while antimony, beryllium, cadmium, nickel, silver, and thallium were detected in 33% or less of the samples. Lead was never detected. The metals present in the highest concentrations were aluminum (up to 16.4 ppm), zinc (up to 6.7 ppm), iron (up to 5.8 ppm), and arsenic (up to 3.5 ppm).

Total DDT, comprised exclusively of p,p-DDE, was detected in 100% of the muscle samples, while the pesticide HCB and PCBs were detected in 8 and 92% of the samples, respectively (Table 7.5). The PCB congener PCB 153/168 was also found in 92% of the samples; the only other PCB congeners measured in the muscle tissue samples were PCB 99, PCB 101, PCB 118, PCB 138, and PCB 187. Concentrations of these contaminants ranged from < 1 ppb for HCB to 8.0 ppb for total DDT.

Of the contaminants detected in muscle tissues during 2009, only the metals arsenic and selenium occurred in concentrations higher than median international standards, while mercury (as a proxy for methylmercury) exceeded the OEHHA fish contaminant goal. Exceedances for arsenic occurred in both California scorpionfish and mixed rockfish muscle samples, while the exeedances for mercury and selenium occurred only in scorpionfish.

In addition to addressing health concerns, spatial patterns were analyzed for total DDT and total PCB, as well as for all metals that occurred frequently in muscle tissue samples (Figure 7.4). Overall, concentrations of DDT, PCB, and various metals in the muscle tissues of fishes captured at rig fishing stations RF3 and RF4 were fairly similar, which suggests that there was no relationship with proximity to the outfall. However, comparisons of contaminant loads in fishes from these stations should be considered with caution since different species of fish were collected at the two sites, and the bioaccumulation of contaminants may differ between species because of differences in physiology, diet, and exposure to contaminant sources due to migration habits and/or other large scale movements. This potential problem may be minimal in the South Bay region as all fish specimens sampled in 2009 have similar life histories (i.e., bottom dwelling tertiary carnivores), and are therefore likely to have similar mechanisms of exposure to and uptake of contaminants (e.g., direct contact with sediments, similar food sources). However, species such as those reported herein are

Table 7.3

Summary of chlorinated pesticides, total PCB, and lipids in liver tissues of fishes collected at SBOO trawl stations during 2009. Data include the number of detected values (*n*), as well as minimum (Min), maximum (Max), and mean detected concentrations for each species. HCB = hexachlorobenzene; tChl = total chlordane; tDDT = total DDT; End. = endrin; tPCB = total PCB; Lip. = lipids. Data are expressed in parts per billion (ppb) for all parameters except lipids, which are presented as percent weight (% wt); the number of samples per species is indicated in parentheses; See Appendix F.2 for MDLs and Appendix F.3 for values of individual constituents summed for total chlordane, total DDT, and total PCB.

	Pesticides					
	HCB	tChl	tDDT	End.	tPCB	Lip.
California scorpionfish						
n (out of 3)	3	2	3	0	3	3
Min	1.9	14.0	719	—	403.7	12
Max	3.3	15.0	1004	—	533.2	21
Mean	2.7	14.5	896	—	474.2	17
English sole						
n (out of 1)	0	0	1	0	1	1
Min	—	—	26	—	18.7	4
Max	—	—	26	—	18.7	4
Mean	—	—	26	—	18.7	4
Hornyhead turbot						
n (out of 13)	4	1	13	1	13	13
Min	1.4	20.3	32	98	7.6	3
Max	4.7	20.3	2802	98	841.9	32
Mean	3.0	20.3	294	98	94.2	8
Longfin sanddab						
n (out of 17)	15	0	17	1	17	17
Min	1.7	—	27	210	2.4	6
Max	3.9	—	1184	210	823.9	33
Mean	3.0	—	645	210	423.0	20
All Species:						
Detection Rate (%)	65	9	100	6	100	100
Max Value	4.7	20.3	2802	210	841.9	33

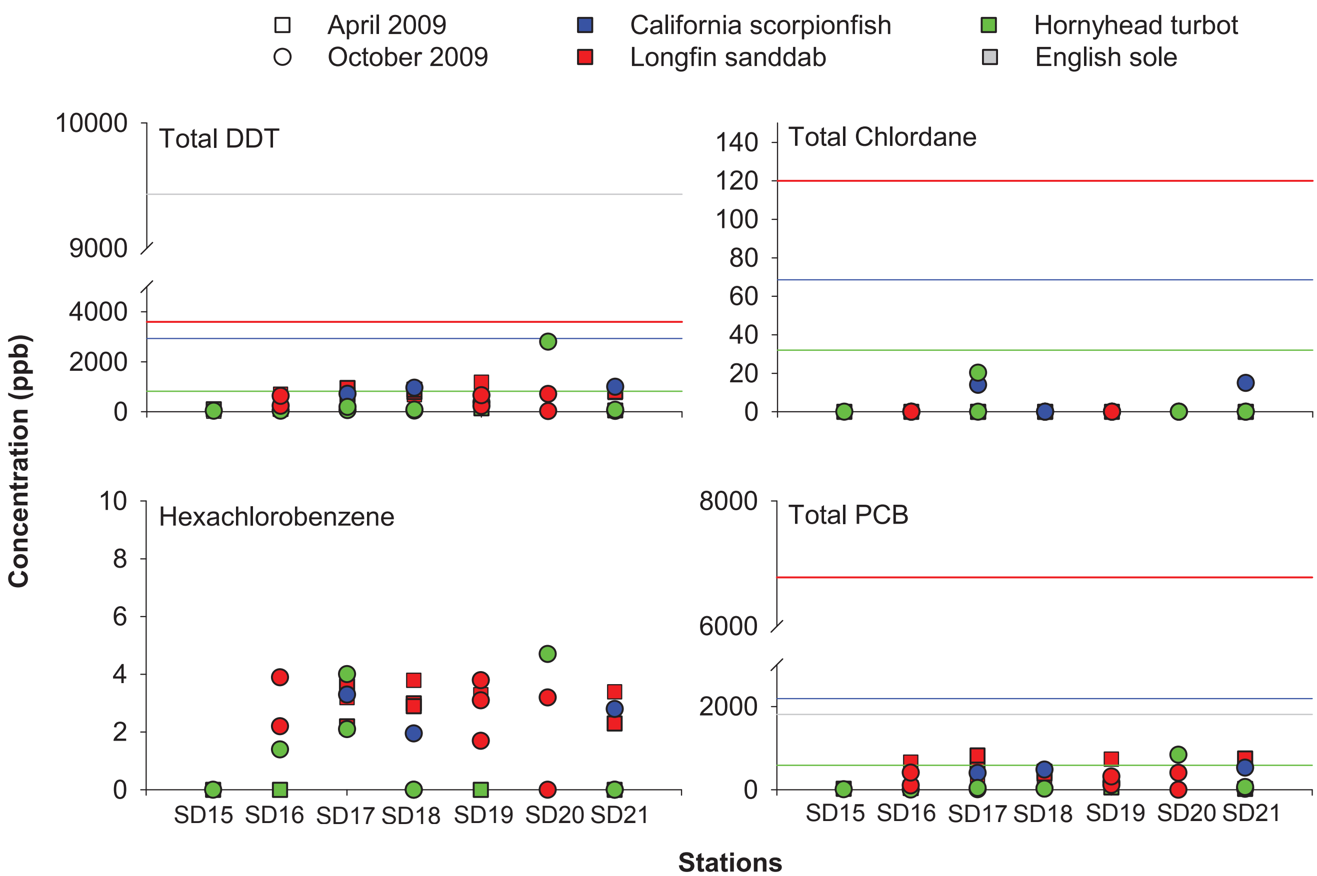

Figure 7.3
Concentrations of frequently detected chlorinated pesticides (total DDT, total chlordane, hexachlorobenzene) and total PCBs in liver tissues of fishes collected from each SBOO trawl station during 2009. Reference lines are maximum values detected during the pre-discharge period (1995–1998) for each species; chlordane and hexachlorobenzene were not detected as frequently during the pre-discharge period because of substantially higher detection limits. Therefore, reference lines for these two contaminants are absent for some or all of the species. To differentiate between missing values (i.e., samples that were not collected or not analyzed; see Table 7.1) and non-detects, zeros were added as placed holders for non-detected values.

known to traverse large areas and may be exposed to contaminants present instead in other locations. For example, it has been previously reported that California scorpionfish tagged in Santa Monica Bay have been recaptured as far south as the Coronado Islands (e.g., Hartmann 1987, Love et al. 1987).

Summary and Conclusions

Several trace metals, the pesticides DDT, HCB, endrin, and various chlordane components, and a combination of PCB congeners were detected in liver tissue samples collected from four different species of fish in the SBOO region during 2009. Many of the same metals, DDT, HCB, and PCBs were also detected in muscle tissues during the year, although less frequently and/or in lower concentrations. Tissue contaminant values ranged widely within and among species and stations. However, all were within the range of values reported previously for the Southern California Bight (SCB) (see Mearns et al. 1991, City of San Diego 1996–2001, Allen et al. 1998). In addition, while some muscle tissue samples from sport fish collected in the area had concentrations of arsenic and selenium above the median international standard for shellfish, and some had concentrations of mercury that exceeded OEHHA fish contaminant goals, concentrations of mercury and DDT were below FDA human consumption limits.

Table 7.4

Summary of metals in muscle tissues of fishes collected at SBOO rig fishing stations during 2009. Data include the number of detected values (*n*), as well as minimum (Min), maximum (Max), and mean detected concentrations for each species. Concentrations are expressed as parts per million (ppm); the number of samples per species is indicated in parentheses. Data are compared to OEHHA fish contaminant goals, U.S. FDA action limits, and median international standards for parameters where these exist. Bold values meet or exceed these standards. See Appendix F.2 for MDLs and names for each metal represented by periodic table symbol.

	Al	Sb	As	Ba	Be	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Tl	Sn	Zn
Brown rockfish																		
n (out of 4)	4	0	4	4	0	0	4	4	2	0	2	4	0	4	1	0	2	4
Min	3.7	—	0.7	0.039	—	—	0.112	0.27	4.5	—	0.14	0.104	—	0.16	0.072	—	1.40	2.6
Max	16.4	—	1.0	0.145	—	—	0.180	0.99	5.8	—	0.16	0.164	—	0.28	0.072	—	1.41	6.7
Mean	9.8	—	0.9	0.088	—	—	0.151	0.68	5.2	—	0.15	0.133	—	0.23	0.072	—	1.40	4.4
California scorpionfish																		
n (out of 6)	6	2	6	5	2	1	6	6	5	0	3	6	1	6	2	2	3	6
Min	5.8	0.103	1.1	0.043	0.017	0.063	0.156	0.25	2.4	—	0.05	0.159	0.111	0.25	0.109	0.565	1.41	3.2
Max	14.7	0.111	**3.5**	0.132	0.025	0.063	0.387	1.71	4.5	—	0.19	**0.275**	0.111	**0.34**	0.113	0.652	1.55	5.7
Mean	9.6	0.107	**2.4**	0.085	0.021	0.063	0.243	0.82	3.4	—	0.14	0.191	0.111	0.29	0.111	0.608	1.50	4.4
Mixed rockfish																		
n (out of 2)	2	1	2	2	0	0	2	2	2	0	1	2	0	2	1	0	1	2
Min	5.0	0.218	**1.4**	0.042	—	—	0.165	0.30	2.4	—	0.20	0.120	—	0.19	0.062	—	1.38	2.9
Max	15.3	0.218	**1.4**	0.162	—	—	0.188	1.34	5.0	—	0.20	0.122	—	0.20	0.062	—	1.38	4.5
Mean	10.2	0.218	**1.4**	0.102	—	—	0.176	0.82	3.7	—	0.20	0.121	—	0.20	0.062	—	1.38	3.7
All Species:																		
Detection Rate (%)	100	25	100	92	17	8	100	100	75	0	50	100	8	100	33	17	50	100
Max Value	16.4	0.218	**3.5**	0.162	0.025	0.063	0.387	1.71	5.8	—	0.20	**0.275**	0.111	**0.34**	0.113	0.652	1.55	6.7
OEHHA*												0.22		7.4				
U.S. FDA Action Limit**												1						
Median IS**			1.4				1	20				0.5		0.3			175	70

* From the California Office of Environmental Health Hazard Assessment (OEHHA) (Klasing and Brodberg 2008).

** From Mearns et al. 1991. U.S. FDA mercury action limits and all international standards (IS) are for shellfish, but are often applied to fish.

Table 7.5

Summary of chlorinated pesticides, total PCB, and lipids in muscle tissues of fishes collected at SBOO rig fishing stations during 2009. Data include the number of detected values (*n*), as well as minimum (Min), maximum (Max), and mean detected concentrations for each species. HCB = hexachlorobenzene; tDDT = total DDT; tPCB = total PCB. Values are expressed in parts per billion (ppb) for all parameters except lipids, which are presented as percent weight (% wt); the number of samples per species is indicated in parentheses. Data are compared to OEHHA fish contaminant goals, U.S. FDA action limits, and median international standards for parameters where these exist. Bold values meet or exceed these standards. See Appendix F.2 for MDLs and Appendix F.3 for values of individual constituents summed for total DDT and total PCB.

	Pesticides			
	HCB	tDDT	tPCB	Lipids
Brown rockfish				
n (out of 4)	1	4	4	4
Min	0.3	1.8	0.2	0.08
Max	0.3	5.7	1.7	0.50
Mean	0.3	3.0	0.7	0.23
California scorpionfish				
n (out of 6)	0	6	5	6
Min	—	1.9	0.3	0.10
Max	—	8.0	3.1	1.07
Mean	—	3.9	1.0	0.40
Mixed rockfish				
n (out of 2)	0	2	2	2
Min	—	2.3	0.7	0.05
Max	—	3.7	0.9	0.28
Mean	—	3.0	0.8	0.16
All Species:				
Detection Rate (%)	8	100	92	100
Max Value	0.3	8.0	3.1	1.07
OEHHA*		21	3.6	
U.S. FDA Action Limit**		5000		
Median IS**		5000		

* From the California Office of Environmental Health Hazard Assessment (OEHHA) (Klasing and Brodberg 2008).

** From Mearns et al. 1991. U.S. FDA action limits and all international standards (IS) are for shellfish, but are often applied to fish.

The frequent occurrence of metals and chlorinated hydrocarbons in SBOO fish tissues may be due to multiple factors. Mearns et al. (1991) described the distribution of several contaminants, including arsenic, mercury, DDT, and PCBs as being ubiquitous in the SCB. In fact, many metals occur naturally in the environment, although little information is available on background levels in fish tissues. Brown et al. (1986) determined that no areas of the SCB are sufficiently free of chemical contaminants to be considered reference sites. This has been supported by more recent work regarding PCBs and DDTs (e.g., Allen et al. 1998, 2002). The lack of contaminant-free reference areas in the SCB clearly pertains to the South Bay outfall region, as demonstrated by the presence of many contaminants in fish tissues prior to wastewater discharge (see City of San Diego 2000b).

Other factors that affect the accumulation and distribution of contaminants include the physiology and life history of different fish species (see Groce 2002 and references therein). Exposure to contaminants can vary greatly between different species and among individuals of the same species depending on migration habits (Otway 1991). Fishes may be exposed to contaminants in an area that is highly contaminated and then move into an area that is not. This is of particular concern for fishes collected in the vicinity of the SBOO, as there are many point and non-point sources that may contribute to contamination in the region (see Chapters 2–4); some monitoring stations are located near the Tijuana River, San Diego Bay, and dredged materials disposal sites, and input from these sources may affect fish in surrounding areas.

Overall, there was no evidence that fishes collected in 2009 were contaminated by the discharge of wastewater from the SBOO. Although several individual tissue samples contained concentrations of some metals that exceeded pre-discharge maximums, concentrations of most contaminants were not substantially different from pre-discharge levels (see City of San Diego 2000b). In addition, the few tissue samples that did exceed pre-discharge values were widely distributed among the sampled stations and showed no patterns that could be attributed to wastewater discharge. Finally, there was no other indication of poor fish health in the region, such as the presence of fin rot, other indicators of disease, or any physical anomalies (see Chapter 6).

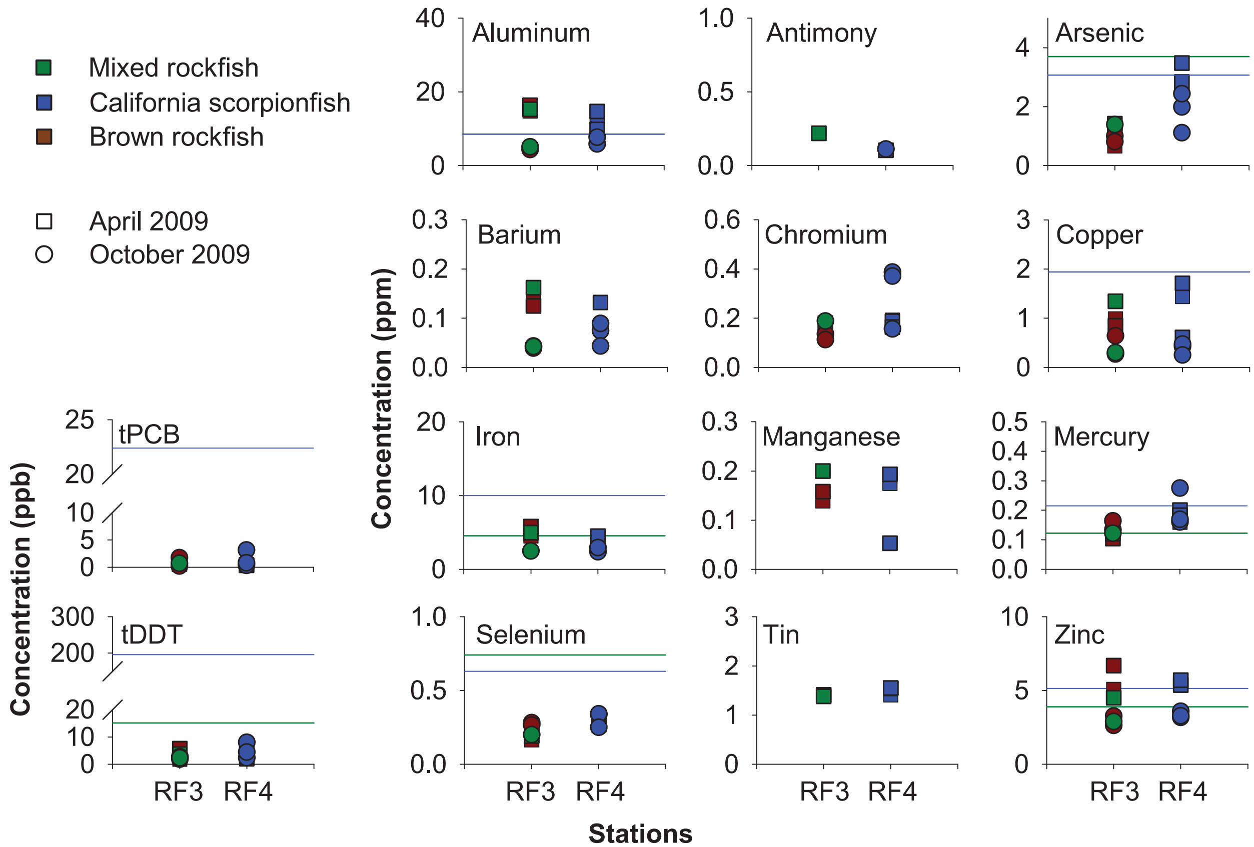

Figure 7.4

Concentrations of frequently detected metals, total (tDDT), and total (tPCB) in muscle tissues of fishes collected from each SBOO rig fishing station during 2009. Reference lines are maximum values detected during the pre-discharge period (1995–1998) for California scorpionfish and mixed rockfish; brown rockfish were not collected during that period. All missing values = non-detects.

Literature Cited

Allen, M.J., S.L. Moore, K.C. Schiff, D. Diener, S.B. Weisburg, J.K. Stull, A. Groce, E. Zeng, J. Mubarak, C.L. Tang, R. Gartman, and C.I. Haydock. (1998). Assessment of demersal fish and megabenthic invertebrate assemblages on the mainland shelf of Southern California in 1994. Southern California Coastal Water Research Project, Westminster, CA.

Allen, M.J., A.K. Groce, D. Diener, J. Brown, S.A. Steinert, G. Deets, J.A. Noblet, S.L. Moore, D. Diehl, E.T. Jarvis, V. Raco-Rands, C. Thomas, Y. Ralph, R. Gartman, D. Cadien, S.B. Weisberg, and T. Mikel. (2002). Southern California Bight 1998 Regional Monitoring Program: V. Demersal Fishes and Megabenthic Invertebrates. Southern California Coastal Water Research Project, Westminster, CA.

Brown, D.A., R.W. Gossett, G.P. Hershelman, C.G. Word, A.M. Westcott, and J.N. Cross. (1986). Municipal wastewater contamination in the Southern California Bight: Part I — Metal and organic contaminants in sediments and organisms. Marine Environmental Research, 18: 291–310.

City of San Diego. (1996). Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 1995. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (1997). Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 1996. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (1998). Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 1997. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (1999). Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 1998. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2000a). Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 1999. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2000b). Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall, 1999. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2000c). International Wastewater Treatment Plant Final Baseline Ocean Monitoring Report for the South Bay Ocean Outfall (1995–1998). City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2001). Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 2000. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2004). Quality Assurance Manual, 2003. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2010). 2009 Annual Reports and Summary: Point Loma Wastewater Treatment Plant and Point Loma Ocean Outfall. City of San Diego, Public Utilities Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

Groce, A.K. (2002). Influence of life history and lipids on the bioaccumulation of organochlorines in demersal fishes. Master's thesis. San Diego State University. San Diego, CA.

Hartmann, A.R. (1987). Movement of scorpionfishes (Scorpaenidae: *Sebastes* and *Scorpaena*) in the Southern California Bight. California Fish and Game, 73: 68–79.

Klasing, S. and R. Brodberg (2008). Development of Fish Contaminant Goals and Advisory Tissue Levels for Common Contaminants in California Sport Fish: Chlordane, DDTs, Dieldrin, Methylmercury, PCBs, Selenium, and Toxaphene. California Environmental Protection Agency, Office of Environmental Health Hazard Assessment, Sacramento, CA.

Lauenstein, G.G. and A.Y. Cantillo, eds. (1993). Sampling and Analytical Methods of the NOAA National Status and Trends Program National Benthic Surveillance and Mussel Watch Projects 1984–1992: Vol. I–IV. Technical Memorandum NOS ORCA 71. NOAA/NOS/ORCA, Silver Spring, MD.

Love, M.S., B. Axell, P. Morris, R. Collins, and A. Brooks. (1987). Life history and fishery of the California scorpionfish, *Scorpaena guttata*, within the Southern California Bight. Fisheries Bulletin, 85: 99–116.

Mearns, A.J., M. Matta, G. Shigenaka, D. MacDonald, M. Buchman, H. Harris, J. Golas, and G. Lauenstein. (1991). Contaminant Trends in the Southern California Bight: Inventory and Assessment. NOAA Technical Memorandum NOS ORCA 62. Seattle, WA.

Otway, N. (1991). Bioaccumulation studies on fish: choice of species, sampling designs, problems and implications for environmental management. In: A.G. Miskiewicz (ed.). Proceedings of a Bioaccumulation Workshop: Assessment of the Distribution, Impacts, and Bioaccumulation of Contaminants in Aquatic Environments. Australian Marine Science Association, Inc./Water Board.

Rand, G.M., ed. (1995). Fundamentals of Aquatic Toxicology: Effects, Environmental Fate, and Risk Assessment. 2nd ed. Taylor and Francis, Washington, D.C.

Schiff, K. and M.J. Allen. (1997). Bioaccumulation of chlorinated hydrocarbons in livers of flatfishes from the Southern California Bight. In: S.B. Weisberg, C. Francisco, and D. Hallock (eds.). Southern California Coastal Water Research Project Annual Report 1995–1996. Southern California Coastal Water Research Project, Westminster, CA.

[U.S. EPA] United States Environmental Protection Agency. (2000). Bioaccumulation Testing and Interpretation for the Purpose of Sediment Quality Assessment. Status and Needs. EPA-823-R-00-001. U.S. Environmental Protection Agency.